POCKET LAB

BOWLING BALL DISPLACEMENT

Take a bowling bowl and stopwatches into the hallway. Divide into three groups. Have all timers start their clocks when the ball is rolled. Group 1 should stop their watches when the ball has gone 10 m. Group 2 should stop when the ball has rolled 20 m, and Group 3 should stop their clocks when the ball has rolled 30 m. Record all data on the chalkboard. Use the distance to calculate the average speed for each distance. Could the average speed for 30 m be used to predict the time needed to roll 100 m? Why? How could the activity be altered to make a better prediction?

Example Problem

Position-Time Graph for a Complete Trip

Figure 3–9 is a position-time graph for a short car trip. Find the velocity of the car for each part of the trip.

Solution: Between points **A** and **B**,

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+200\text{ m}}{10\text{ s}} = +20\text{ m/s}$$

Between point **B** and **C**, the line is horizontal.

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+0\text{ m}}{10\text{ s}} = +0\text{ m/s}$$

The car is at rest.

Between points **C** and **D**, the position of the car decreases; the displacement is negative.

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{-50\text{ m}}{5.0\text{ s}} = -10\text{ m/s}$$

The slope and velocity are both negative; the car moves in a direction opposite to its original direction. Between points **D** and **E**,

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{-250\text{ m}}{20\text{ s}} = -13\text{ m/s}$$

The slope and velocity are both more negative. The velocity has the same negative value for the entire segment, even though the position at point **E** is negative. That is, the car passed its starting point. Between points **E** and **F**,

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+100\text{ m}}{15\text{ s}} = +6.7\text{ m/s}$$

The velocity again is positive. The car is moving again in its original direction.

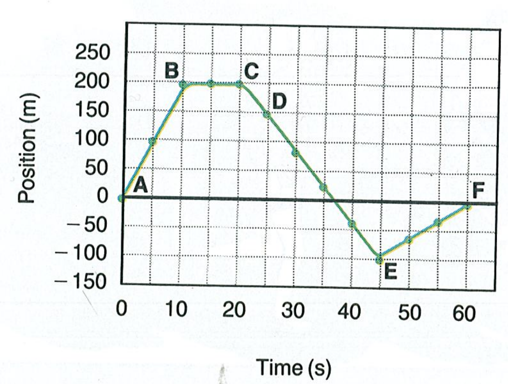
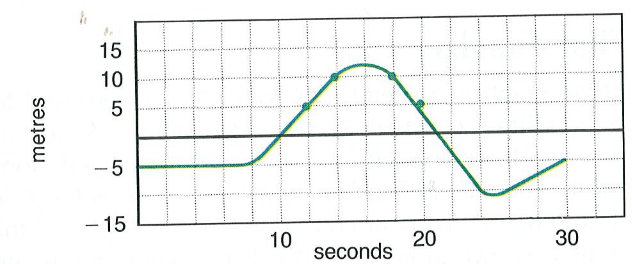


FIGURE 3–9. A position-time graph for a short car trip.

Practice Problems

9. Describe in words the motion of the four walkers shown in the four curves in Figure 3–10. Assume the positive direction is east and the reference point is the corner of High Street.
10. Sketch position-time graphs for these four motions:
    a. starting at a positive position with a positive velocity.
    b. starting at a negative position with a smaller positive velocity.
    c. remaining at a negative position.
    d. starting at a positive position with a negative velocity.
11. Find the average velocities shown in Figure 3–11.
    a. between t = 10 and 12 s
    b. between t = 14 and 18 s
    c. between t = 20 and 24 s
    d. between t = 26 and 30 s



▶ 12. Draw a position-time graph of a moving elevator. Use the first floor as the reference point and up as positive. The elevator waits on the first floor for 30 s, rises to the third floor in 20 s, stops for 30 s, then goes to the basement, which it reaches in 40 s.

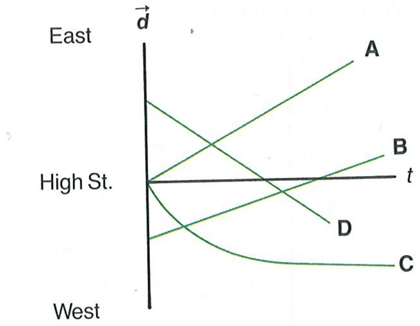


FIGURE 3–10. Use with Practice Problem 9.

FIGURE 3–11. Use with Practice Problem 11.

Instantaneous Velocity

To find the velocity of a car, you use its speedometer. Suppose the speedometer needle swings upward from 70 to 90 km/h. What is the car doing? The car is obviously speeding up. If you glance at the speedometer and see the needle at 80 km/h, what does that mean? It means that at the instant you looked, the car's velocity was 80 km/h. Its instantaneous velocity was 80 km/h. That is, if the velocity had been constant, the car would have driven 80 km in 1 h.

A position-time graph can be used to find instantaneous velocity. Figure 3–12a is a position-time graph of a runner during a 100 m dash. Figure 3–12b shows the first 2.5 s of the dash. If the person had a speedometer, what would it read at 1.0 s? Start by finding the average velocity between 0.0 s and 2.0 s. The rise, the runner's displacement, is 12.5 m, while the run, the time interval, is 2.0 s. The slope of the line connecting these two points is the average velocity during this time interval, 6.3 m/s. Next, find the average velocity between 0.5 s and 1.5 s. Now the displacement is 6.8 m while the time interval is 1.0 s. The slope of the connecting line, the average velocity, is 6.8 m/s. We could continue this process, choosing the time interval smaller and smaller until the two clock readings are almost the same. We can no longer draw a line connecting the two points. We now draw a straight line that is the tangent to the curve at that point. The slope of the tangent is called the **instantaneous velocity** at that instant.

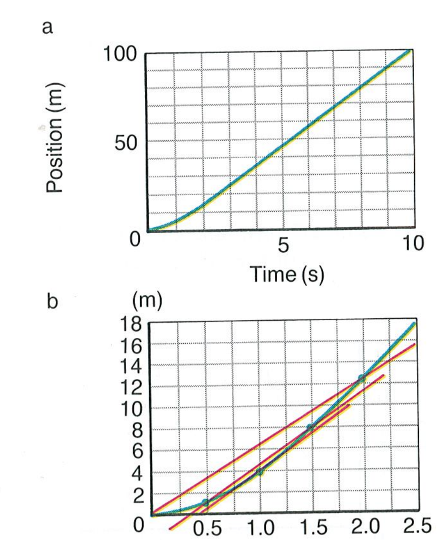
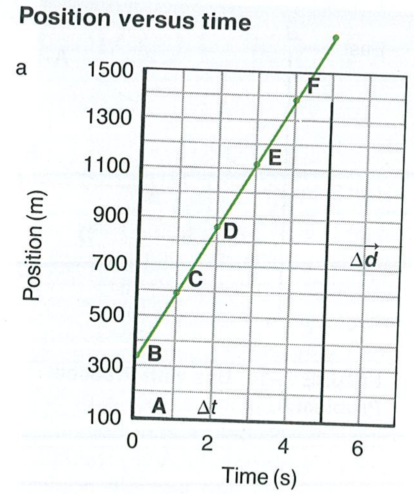


FIGURE 3–12. A position-time graph (a) can be used to find instantaneous velocities by determining the slope at various times (b).



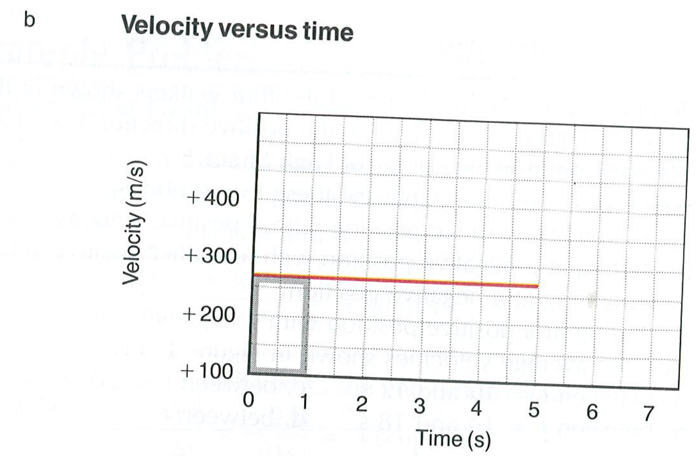


FIGURE 3–13. The velocity-time graph for an airplane moving with a constant velocity of 260 m/s.

The displacement between two times is the area under the curve of a velocity-time graph.

The instantaneous velocity is the tangent to a curve on a position-time graph.

Velocity-Time Graphs

A **velocity-time graph** is a useful new tool that can be used to describe motion with either constant or changing velocity. Again, model the motion shown in the graph with the motion of your hand along the edge of your desk. The data in Figure 3–5 were used to plot a position-time graph of an airplane flying at constant velocity. A plot of the velocity versus time is shown in Figure 3–13. Every point on the line has the same vertical value because the velocity is constant. The line is parallel to the *t*-axis.

How would you describe the motion of the runner shown in the velocity-time graph in Figure 3–14? The vertical value of any point is the instantaneous velocity at that time. During the first 5 s, the runner's instantaneous velocity increases. For the next 5 s, he runs at a constant 8 m/s, and over the last 3 s, he slows to a stop.

Example Problem

Finding Displacement from a Velocity-Time Graph

Find the displacement of the plane whose velocity is shown in Figure 3–13 at **a.** 1.0 s. **b.** 3.0 s.

Given: $\vec{v}$-t graph, Figure 3–13b
time intervals,
a. 0.0 s to 1.0 s
b. 0.0 s to 3.0 s

Unknown: displacement, $\Delta\vec{d}$
Basic equation: area under graph,
$\Delta\vec{d} = \vec{v}\Delta t$

Solution:

Note shaded area under line in Figure 3–13b. The vertical side is velocity: $\vec{v} = +260$ m/s.

a. Horizontal side is time interval: $t = 1.0$ s;
the area of rectangle under the line is

$$\vec{v}\Delta t = (+260 \text{ m/s})(1.0 \text{ s}) = 2.6 \times 10^2 \text{ m}.$$

This quantity is the displacement in 1.0 s.

b. At the end of 3.0 s, the area under the line is

$$\vec{v}\Delta t = (+260 \text{ m/s})(3.0 \text{ s}) + 7.8 \times 10^2 \text{ m};$$

the displacement of the plane in 3.0 s.

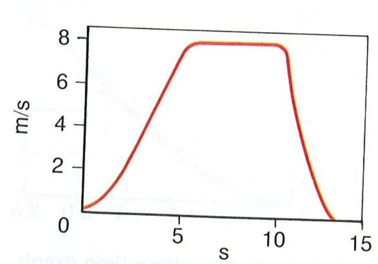


FIGURE 3–14. A velocity-time graph shows the instantaneous velocity of the runner at every instant.

Thus, the area under the line on a velocity-time graph is equal to the displacement of the object from its original position to its position at time *t*. When velocity is constant, displacement increases linearly with time. If you plot the displacement versus time, you will get a straight line with a slope equal to the velocity.

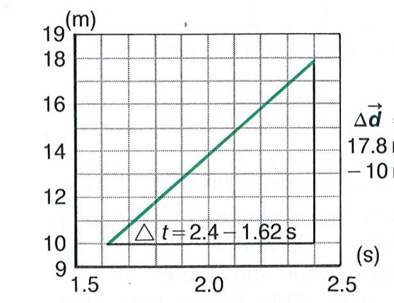


FIGURE 3–15. Use with Practice Problem 13.

Practice Problems

13. Using Figure 3–15 find the sprinter's velocity at 2.0 s.

14. Use your hand on your desk to model the motion shown by the curves in Figure 3–16a below. Describe in words the motions.

15. Figure 3–16b is the velocity-time graph of an object. What is its velocity at
a. 0 s? **b.** 1 s? **c.** 2 s?

16. Using the graph in Figure 3–16b, describe how the instantaneous velocity changes with time.

17. Sketch velocity-time graphs for the graphs in Figure 3–16c.

18. A car moves along a straight road at a constant velocity of +75 km/h for 4.0 h, stops for 2.0 h, and then drives in the reverse direction at the original speed for 3.0 h.
a. Plot a velocity-time graph for the car.
b. Find the area under the curve for the first 4.0 h. What does this represent?
c. Explain how to use the graph to find the distance the car is from its starting point at the end of 9.0 h.

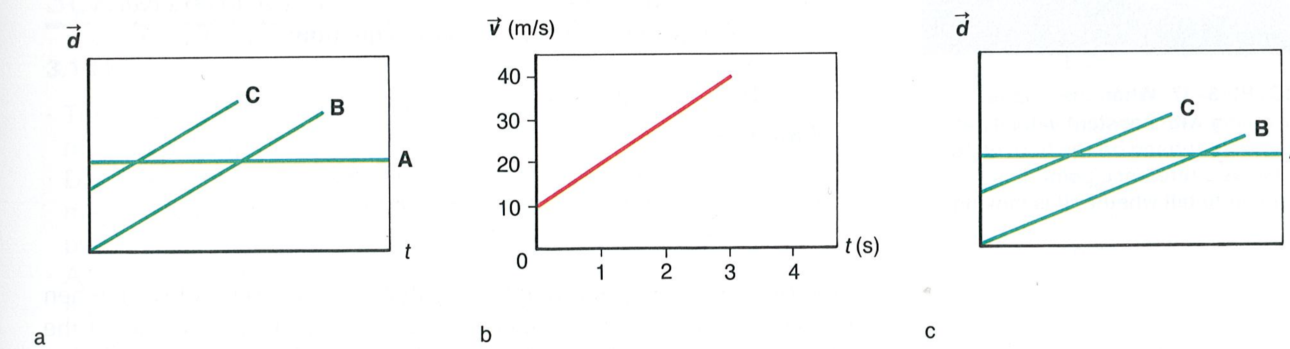


FIGURE 3–16. Use with Practice Problems 14, 15, 16, and 17.

▶**19.** A person drives a car at a constant +25 m/s for 10.0 min. The car runs out of gas, so the driver, carrying an empty gasoline can, walks at +1.5 m/s for 20.0 min to the nearest gas station. After the 10.0 min needed to fill the can, the driver walks back to the car at a slower −1.2 m/s. The car is then driven home at −25 m/s.
a. Draw a velocity-time graph for the driver, using seconds as your time unit. You will have to calculate the distance the driver walked to the station in order to find the time needed to walk back to the car.
b. Draw a position-time graph for the problem from the areas under the curves of the velocity-time graph.

7. A walker and a runner leave your front door at the same time. They move in the same direction at different constant velocities. Describe the position-time graphs of each.
8. If you know the positions of a particle at two points along its path and also know the time it took to get from one point to the other, can you determine the particle's instantaneous velocity? its average velocity? Explain.
9. What quantity is represented by the area under a velocity-time curve?
10. Figure 3–19 shows a velocity-time graph for an automobile on a test track. Describe the changes in velocity with time.

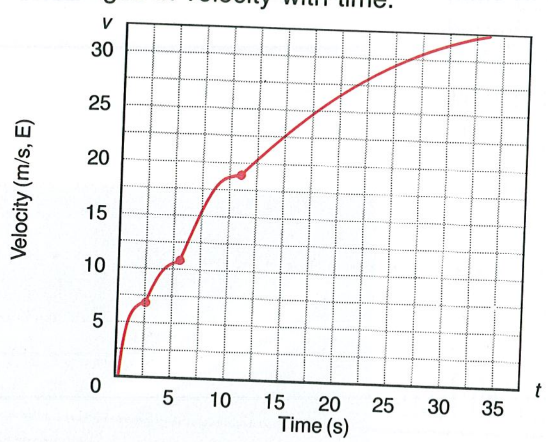


FIGURE 3–19. Use with Reviewing Concepts 10 and Problem 22.

APPLYING CONCEPTS

1. If the scale in Figure 3–1 was moved 3 m to the right, would the position of each car remain the same?
2. If the scale in Figure 3–1 was moved 3 m to the right, would the distance between the cars remain the same?
3. A NASA team oversees a space shuttle launch at Cape Kennedy in Florida and then travels to Edwards Air Force Base in California to supervise the landing. Which group of people, the astronauts or the NASA team, has the greater displacement?
4. Average velocity is $\Delta\vec{d}/t$. Consider the ratio $\Delta t/\vec{d}$. When is this new ratio large? When is it small? Can it ever be zero? Invent a reasonable name for it.
5. If the average velocity of a particle is zero in some time interval, what can you say about its displacement for that interval?

6. Look at Figure 3–20a.
   a. What kind of motion does this graph represent?
   b. What does the slope of the line represent?
7. Use the intervals marked on the graph in Figure 3–20b to describe the velocity of the object during each interval.

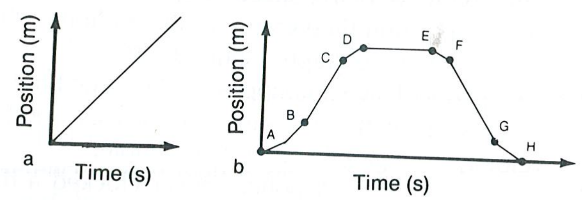


FIGURE 3–20. Use with Applying Concepts 6 and 7 (b).

8. Figure 3–21 is a position-time graph of two people running.
   a. Describe the position of runner A relative to runner B at the *y*-intercepts.
   b. Which runner is faster?
   c. What occurs at point **P** and beyond?

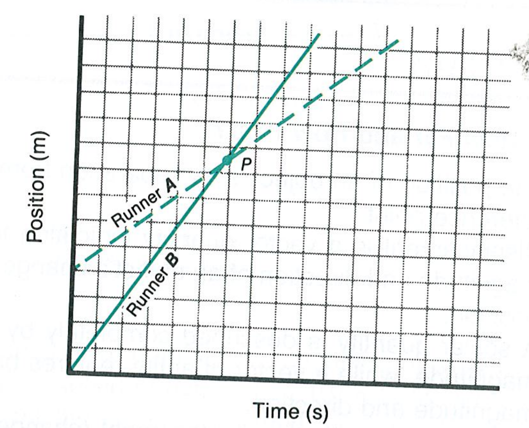


FIGURE 3–21. Use with Applying Concepts 8.

9. Figure 3–22 is a position-time graph of the motion of two cars on a road.
   a. At what time(s) does one car pass the other?
   b. Which car is moving faster at 7.0 s?
   c. At what time(s) do the cars have the same velocity?
   d. Over what time interval is car B speeding up all the time?
   e. Over what time interval is car B slowing down all the time?

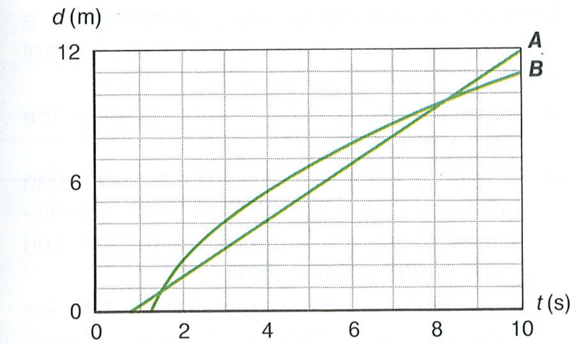


FIGURE 3–22. Use with Applying Concepts 9 and Problem 21.

10. Look at Figure 3–23a.
    a. What kind of motion does this graph represent?
    b. What does the area under the curve of the graph represent?
11. Look at Figure 3–23b.
    a. What kind of motion does this graph represent?
    b. What does the area under the curve of the graph represent?

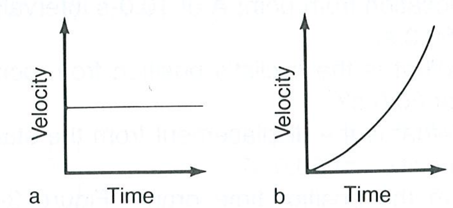


FIGURE 3–23. Use (a) with Applying Concepts 10, (b) with Applying Concepts 11.

PROBLEMS

3.1 How Far and How Fast?

1. While John is travelling along a highway, he notices a 160-km marker as he passes through town. Later John passes another marker, 115 km.
   a. What is the distance between town and John's current location?
   b. What is John's current position?
2. While John is travelling along a straight highway, he notices that the marker reads 260 km. John travels until he reaches the 150-km marker and then retraces his path to the 175-km marker. What is John's resultant displacement from the 260-km marker?
3. A physics book is moved once around the perimeter of a table of dimensions 1.0 m by 2.0 m.
   a. If the book ends up at its initial position, what is its displacement?
   b. What is the distance travelled?
4. Light from the sun reaches Earth in 8.3 min. The speed of light is 3.00×10^8 m/s. How far is Earth from the sun?
5. You and a friend each drive 50 km. You travel at 90 km/h, your friend at 95 km/h. How long will your friend wait for you at the end of the trip?
6. From the list of winning times from the 1988 Summer Olympics track events in Table 3–2, calculate the average speeds for each race. Assume the length of each event is known to the nearest 0.1 m.

Table 3–2

Length of event (m)	Time (min:s)	
	Men	Women
100	0.09.92	0:10.54
200	0:19.75	0:21.34
400	0:43.87	0:48.65
800	1:44.06	1:56.10
1 500	3:35.96	3:53.96
3 000		8:26.53
5 000	13:11.70	
10 000	27:21.46	31:05.21

7. Construct a table similar to Table 3–2 listing average speeds for track events in your school, school board, or province.
8. Construct an average speed table similar to Problem 6 for swimming events at your school, district, or state. Compare speeds for swimming to those for running. Explain.
9. Two cars approach each other; both cars are moving westward, one at 78 km/h, the other at 64 km/h.
   a. What is the velocity of the first car relative to (in the frame of reference of) the second car?
   b. After they pass, will their relative velocity change?

10. Ann is driving down a street at 55 km/h. Suddenly a child runs into the street. If it takes Ann 0.75 s to react and apply the brakes, how many metres will she have moved before she begins to slow down?

11. You plan a trip on which you want to average 90 km/h. You cover the first half of the distance at an average speed of only 48 km/h. What must your average speed be in the second half of the trip to meet your goal? Note that the velocities are based on half the distance, not half the time. Is this reasonable?

12. You drive a car 2.0 h at 40 km/h, then 2.0 h at 60 km/h.
 a. What is your average velocity?
 b. Do you get the same answer if you drive 100 km at each of the two speeds above?

13. The total distance a steel ball rolls down an incline at various times is given in Table 3–3.
 a. Draw a position-time graph of the motion of the ball. When setting up the axes, use five divisions for each 10 m of travel on the $\vec{d}$-axis. Use five divisions for each second of time on the *t*-axis.
 b. What type of curve is the line of the graph?
 c. What distance has the ball rolled at the end of 2.2 s?

Table 3–3

Time (s)	Distance (m)
0.0	0.0
1.0	2.0
2.0	8.0
3.0	18.0
4.0	32.9
5.0	50.0

14. Use the position-time graph in Figure 3–24 to find how far the object travels
 a. between $t = 0$ s and $t = 40$ s.
 b. between $t = 40$ s and $t = 70$ s.
 c. between $t = 90$ s and $t = 100$ s.

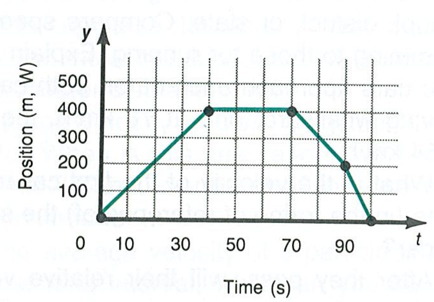


FIGURE 3–24. Use with Problem 14 and 19.

15. Both car A and car B leave school when a clock reads zero. Car A travels at a constant 75 km/h, while car B travels at 85 km/h.
 a. Draw a position-time graph showing the motion of both cars.
 b. How far are the two cars from school when the clock reads 2.0 h? Calculate the distances using the equation of motion and show them on your graph.
 c. Both cars passed a gas station 100 km from the school. When did each car pass the station? Calculate the times and show them on your graph.

16. Draw a position-time graph for two cars driving to the beach, 50 km from school. Car A leaves a store 10 km from school closer to the beach at noon, and drives at 40 km/h. Car B starts from school at 12:30 P.M. and drives at 100 km/h. When does each get to the beach?

17. Plot the data in Table 3–1 on a position-time graph. Find the average velocity in the time interval between 0.0 s and 5.0 s.

18. A cyclist maintains a constant velocity of +5.0 m/s. At time $t = 0$, the cyclist is +250 m from point **A**.
 a. Plot a position-time graph of the cyclist's location from point **A** at 10.0-s intervals for 60.0 s.
 b. What is the cyclist's position from point **A** at 60.0 s?
 c. What is the displacement from the starting position at 60.0 s?

19. From the position-time graph, Figure 3–24, construct a table showing the average velocity of the object during each 10-s interval over the entire 100 s.

20. Two cars travel along a straight road. When a stopwatch reads $t = 0.00$ h, car A is at $\vec{d}_A = 48.0$ km moving at a constant 36.0 km/h. Later, when the watch reads $t = 0.50$ h, car B is at $\vec{d}_B = 0.00$ km moving at 48.0 km/h. Answer the following questions: first, graphically by creating a position-time graph; second, algebraically by writing down equations for the position $\vec{d}_A$ and $\vec{d}_B$ as a function of the stopwatch time, *t*.
 a. What will the watch read when car B passes car A?
 b. At what position will the passing occur?
 c. When the cars pass, how long will it have been since car A was at the reference point?

3.2 New Meaning for Old Words

21. Refer to Figure 3–22 to find the instantaneous speed for
 a. car B at 2.0 s. c. car A at 2.0 s.
 b. car B at 9.0 s.

22. Find the instantaneous speed of the car at 15 s from Figure 3–19.

23. Plot a velocity-time graph using the information in Table 3–4.

Table 3–4

Time (s)	Velocity (m/s)	Time (s)	Velocity (m/s)
0.0	4.0	7.0	12.0
1.0	8.0	8.0	8.0
2.0	12.0	9.0	4.0
3.0	14.0	10.0	0.0
4.0	16.0	11.0	−4.0
5.0	16.0	12.0	−8.0
6.0	14.0		

24. Refer to Figure 3–25 to find the distance the moving object travels between
 a. $t = 0$ s and $t = 5$ s.
 b. $t = 5$ s and $t = 10$ s.
 c. $t = 10$ s and $t = 15$ s.
 d. $t = 0$ s and $t = 25$ s.

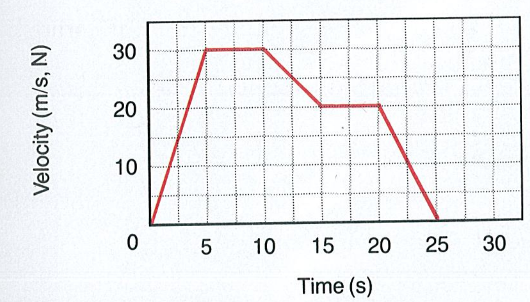


FIGURE 3–25.

25. The velocity of an automobile changes over an 8.0-s time period as shown in Table 3–5.
 a. Plot the velocity-time graph of the motion.
 b. Determine the distance the car travels during the first 2.0 s.
 c. What distance does the car travel during the first 4.0 s?
 d. What distance does the car travel during the entire 8.0 s?

Table 3–5

Time (s)	Velocity (m/s)	Time (s)	Velocity (m/s)
0.0	0.0	5.0	20.0
1.0	4.0	6.0	20.0
2.0	4.0	7.0	20.0
3.0	8.0	8.0	20.0
4.0	16.0		

USING A GRAPHING CALCULATOR

Members of a physics class stood 25 m apart and used stopwatches to measure the time a car driving down the highway passed each person. They compiled their data into the following table:

Table 3–6

Time (s)	Position (m)	Time (s)	Position (m)
0.0	0.0	5.9	125.0
1.3	25.0	7.0	150.0
2.7	50.0	8.6	175.0
3.6	75.0	10.3	200.0
5.1	100.0		

Use a graphing calculator to fit a line to a position-time graph the data and to plot this line. Be sure to set the display range of the graph so that all the data fits on it. Find the slope of the line. What was the speed of the car?

THINKING PHYSIC-LY

On some toll roads in the United States, the ticket is stamped with the time you enter the toll road and the time you exit. How can the toll taker determine if you were speeding?

4. $\vec{v}_{AVE} = (\vec{d}_2 - \vec{d}_1)/(t_2 - t_1)$
$= (35\text{ m} - 30\text{ m})/(2.0\text{ s} - 0.0\text{ s})$
$= 2.5\text{ m/s}$

5. Using $\vec{d} = \vec{v}t$ with $\vec{v} = 10$ m/s:

t	$\vec{d}$
1 h = 3600 s	3.6×10^4 m
1 min = 60 s	6.0×10^2 m
1 s	10 m
1 ms = 10^{-3} s	10×10^{-3} m = 10 mm
1 μs = 10^{-6} s	10×10^{-6} m = 10 μm
1 ns = 10^{-9} s	10×10^{-9} m = 10 nm

6. a. $\vec{v} = \dfrac{\vec{d}}{t}$, so $t = \dfrac{\vec{d}}{\vec{v}} = (1620.0\text{ m})/(36.0\text{ m/s})$
$= 45.0$ s

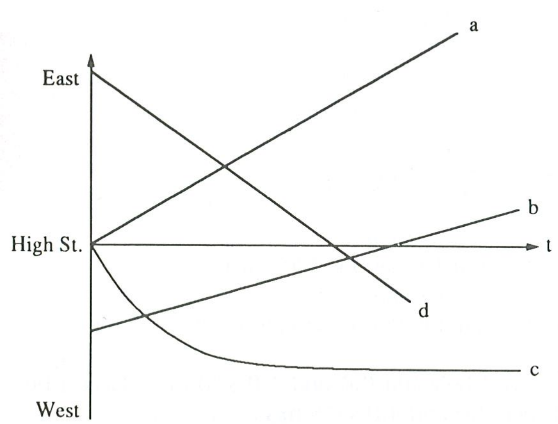
b. $\vec{v} = (36.0\text{ m/s})(1\text{ km}/1000\text{ m})(3600\text{ s}/1\text{ h})$
$= 130$ km/h

7. $\vec{v}_{AVE} = (\vec{d}_2 - \vec{d}_1)/(t_2 - t_1)$ with $t_2 - t_1 = 2.5$ h
$\vec{d}_2 = \vec{d}_1 + \vec{v}_{AVE}(t_2 - t_1)$
$= 17\text{ km} + (94\text{ km/h})(2.5\text{ h})$
$= 252$ km west of school

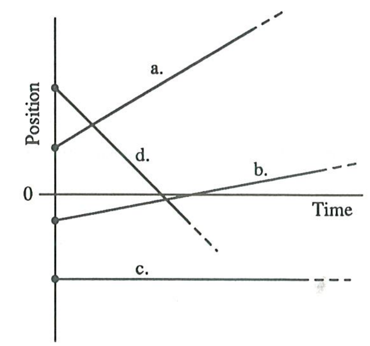
8. a. Same displacement, but position is
$-17\text{ km} + 235\text{ km} = 218$ km west of school.

b. $\Delta t = \dfrac{\Delta\vec{d}}{\vec{v}_{AVE}} = (17\text{ km})/(94\text{ km/h}) = 11$ min, so
$t = 1{:}11$ P.M.

9. a. Starting at High St., walking east at a constant velocity.
b. Starts west of High St., walking east at slower constant velocity.
c. Walks west from High St., first fast, but slowing to a stop.
d. Starts east of High St., walking west at constant velocity.



10.

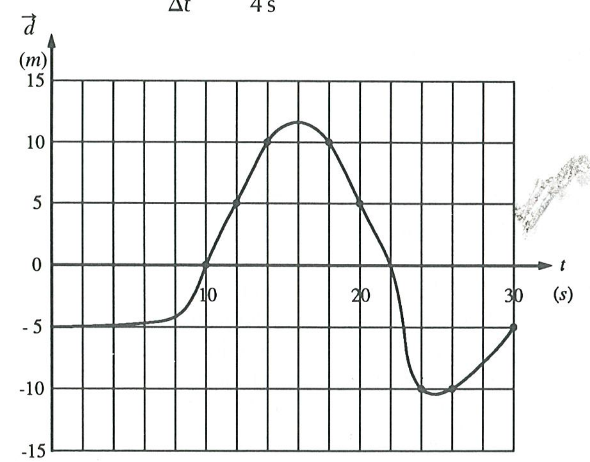


11. a. $\vec{v}_{AVE} = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{+5\text{ m}}{2\text{ s}} = 2.5$ m/s

b. $\vec{v}_{AVE} = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{0\text{ m}}{4\text{ s}} = 0$ m/s

c. $\vec{v}_{AVE} = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{-15\text{ m}}{4\text{ s}} = -3.75$ m/s

d. $\vec{v}_{AVE} = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{+5\text{ m}}{4\text{ s}} = 1.25$ m/s



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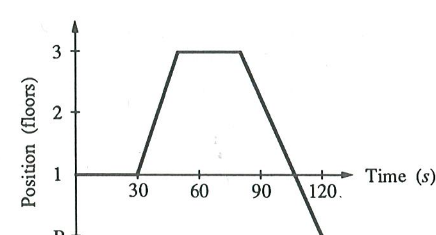
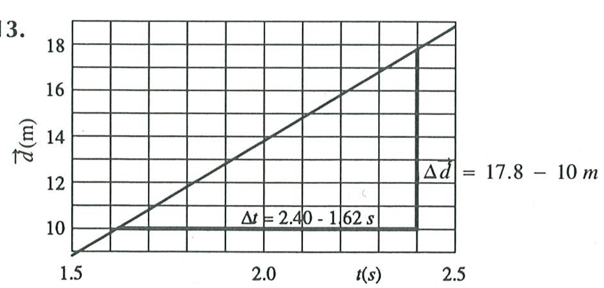


13.



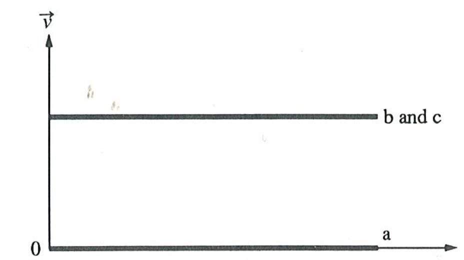
$\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{7.8\,m}{0.78\,s} = 10\ m/s$

14. a. Move to right at constant velocity.
b. Moves to right from rest at constantly increasing velocity.
c. Has an initial non-zero velocity to the right and continues to move to right at constantly increasing velocity.

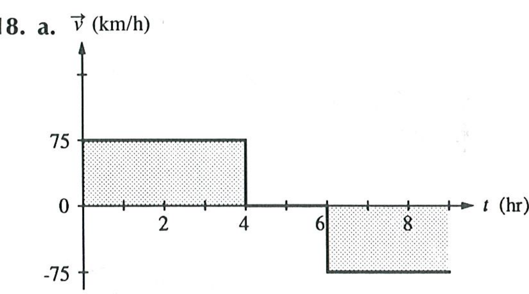
15. a. 10 m/s
b. 20 m/s
c. 30 m/s

16. Each second it increases 10 m/s.

17.

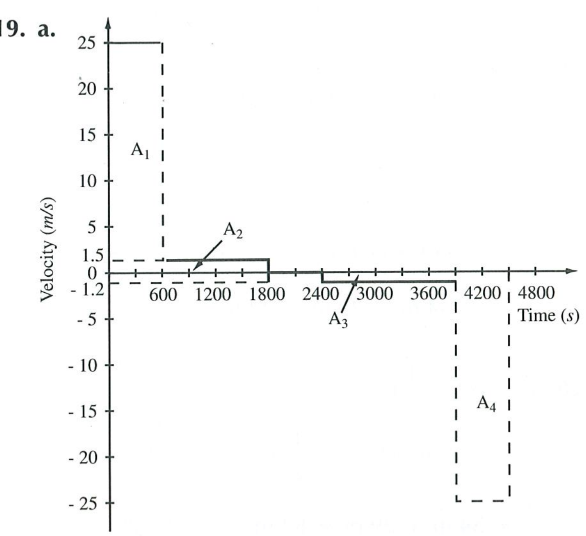


18. a.



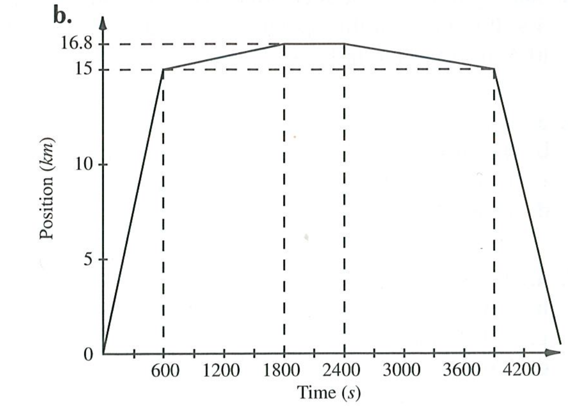
b. Area is $(75\text{ km/h})(4\text{ h}) = 300$ km, the displacement in that time.
c. Find total area under curve for all three segments of trip, which is
$300\text{ km} + 0\text{ km} + (-225\text{ km}) = 75$ km.

19. a.



Displacement to station
$= (1.5\text{ m/s})(20.0\text{ min})(60\text{ s/min})$
$= 1800$ m.
Time for walk back to car
$= (1800\text{ m})/(1.2\text{ m/s})$
$= 1500$ s.

b.



From the graph in part **a**, the changes in position are
$\Delta\vec{d}_1 = A_1 = (25\text{ m/s})(600\text{ s})$
$= 15\,000\text{ m} = 15$ km
$\Delta\vec{d}_2 = A_2 = (1.5\text{ m/s})(1200\text{ s})$
$= 1800\text{ m} = 1.8$ km
$\Delta\vec{d}_3 = A_3 = (-1.2\text{ m/s})(1500\text{ s})$
$= -1800\text{ m} = -1.8$ km
$\Delta\vec{d}_4 = A_4 = (-25\text{ m/s})(600\text{ s})$
$= -15\,000\text{ m} = -15$ km

20. If $\vec{v}_B = \vec{v}_A + \vec{v}_{BA}$, where $\vec{v}_A$, $\vec{v}_B$ are velocities relative to Earth and $\vec{v}_{BA}$ is the velocity of B relative to A, then $\vec{v}_{BA} = \vec{v}_B = \vec{v}_A$.
a. $\vec{v}_{tc} = \vec{v}_t - \vec{v}_c = 105\text{ km/h} - 92\text{ km/h}$
$= 13$ km/h
b. $\vec{v}_{ct} = \vec{v}_c - \vec{v}_t = 92\text{ km/h} - 105\text{ km/h}$
$= -13$ km/h

21. The relative speed is $(3.5\text{ m})/(1.8\text{ s}) = 1.9$ m/s $= 7.0$ km/h, so its speed is 102 km/h.

Chapter 4

1. $\vec{a} = \dfrac{\Delta\vec{v}}{\Delta t} = (36\text{ m/s} - 4.0\text{ m/s})/(4.0\text{ s}) = 8.0\text{ m/s}^2$

2. $\vec{a} = (\vec{v}_2 - \vec{v}_1)/(t_2 - t_1) = (15\text{ m/s} - 36\text{ m/s})/(3.0\text{ s})$
$= -7.0\text{ m/s}^2$

3. $\vec{a} = (\vec{v}_2 - \vec{v}_1)/(t_2 - t_1)$
$= (4.5\text{ m/s} - (-3.0\text{ m/s}))/(2.5\text{ s})$
$= 3.0\text{ m/s}^2$

Appendix B
Supplemental Problems

There are no supplemental problems for Chapter 1.

Chapter 2

1. Express the following numbers in scientific notation.
a. 810 000 g
b. 0.000634 g
c. 60 000 000 g
d. 0.0000010 g

2. Convert each of the following time measurements to its equivalent in seconds.
a. 58 ns
b. 0.046 Gs
c. 9270 ms
d. 12.3 ks

3. Solve the following problems. Express your answers in scientific notation.
a. 6.2×10^{-4} m + 5.7×10^{-3} m
b. 8.7×10^{8} km − 3.4×10^{7} km
c. (9.21×10^{-5} cm) (1.83×10^{8} cm)
d. (2.63×10^{-6} m) ÷ (4.08×10^{6} s)

4. State the number of significant digits in the following measurements.
a. 3218 kg
b. 60.080 kg
c. 801 kg
d. 0.000534 kg

5. State the number of significant digits in the following measurements.
a. 5.60×10^{8} m
b. 3.0005×10^{-6} m
c. 8.0×10^{10} m
d. 9.204×10^{-3} m

6. Add or subtract as indicated and state the answer with the correct number of significant digits.
a. 85.26 g + 4.7 g
b. 1.07 km + 0.608 km
c. 186.4 kg − 57.83 kg
d. 60.08 s − 12.2 s

7. Multiply or divide as indicated using significant digits correctly.
a. (5×10^{8} m) (4.2×10^{7} m)
b. (1.67×10^{-2} km) (8.5×10^{-6} km)
c. (2.6×10^{4} kg) ÷ (9.4×10^{3} m^3)
d. (6.3×10^{-1} m) ÷ (3.8×10^{2} s)

8. A rectangular room is 8.7 m by 2.41 m.
a. What length of baseboard molding must be purchased to go around the perimeter of the floor?
b. What area must be covered if floor tiles are laid?

▶ **9.** The following data table was established showing the total distances an object fell during various lengths of time.

Time (s)	Distance (m)
1.0	5
2.0	20
3.0	44
4.0	78
5.0	123

a. Plot distance vs time from the values given in the table and draw a curve that best fits all points.
b. Describe the resulting curve.
c. According to the graph, what is the relationship between distance and time for a free-falling object?

▶ **10.** The total distance a lab cart travels during specified lengths of time is given in the following table.

Time (s)	Distance (m)
1.0	0.32
2.0	0.60
3.0	0.95
4.0	1.18
5.0	1.45

a. Plot distance vs time from the values given in the table and draw the curve that best fits all points.
b. Describe the resulting curve.
c. According to the graph, what type of relationship exists between the total distance traveled by the lab cart and the time?
d. What is the slope of this graph?
e. Write an equation relating distance and time for this data.

11. Solve the equation

$$F = \frac{mv^2}{r}$$

a. for *m*. **b.** for *r*. **c.** for *v*.

▶ **12.** Solve the equation for d_o.

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

▶ **13.** A cube has an edge of length 5.2 cm.
a. Find its surface area.
b. Find its volume.

14. A truck is traveling at a constant velocity of 70 km/h. Convert the velocity to m/s.

15. The density of gold is 19.3 g/cm^3. A gold washer has an outside radius of 4.3 cm and an inside radius of 2.1 cm. Its thickness is 0.14 cm. What is the mass of the washer?

Chapter 3

1. Bob walks 80 m and then he walks 125 m.
a. What is Bob's displacement if he walks east both times?
b. What is Bob's displacement if he walks east then west?
c. What distance does Bob walk in each case?

2. A cross-country runner runs 5.0 km east along the course, then turns around and runs 5.0 km west along the same path. She returns to the starting point in 40 min. What is her average speed? her average velocity?

3. 0.30 s after seeing a puff of smoke rise from the starter's pistol, the sound of the firing of the pistol is heard by the track timer 100 m away. What is the velocity of sound?

▶ **4.** The radius of the tires on a particular vehicle is 0.62 m. If the tires are rotating 5 times per second, what is the velocity of the vehicle?

5. A bullet is fired with a speed of 720.0 m/s.
a. What time is required for the bullet to strike a target 324 m away?
b. What is the velocity in km/h?

6. Light travels at 3.0×10^{8} m/s. How many seconds go by from the moment the starter's pistol is shot until the smoke is seen by the track timer 100 m away?

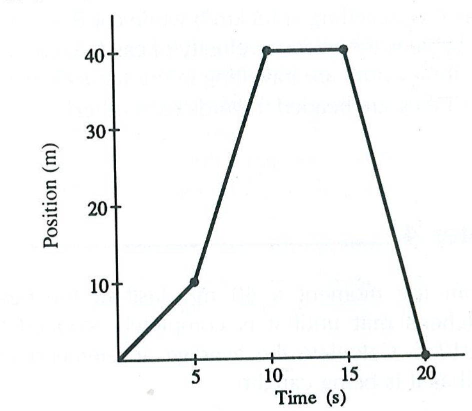
▶ **7.** You drive your car from home at an average velocity of 80 km/h for 3 h. Halfway to your destination, you develop some engine problems, and for 5 h you nurse the car the rest of the way. What is your average velocity for the entire trip?

▶ **8.** The total distance a ball is off the ground when thrown vertically is given for each second of flight by the following table.

Time (s)	Distance (m)
0.0	0.0
1.0	24.5
2.0	39.2
3.0	44.1
4.0	39.2
5.0	24.5
6.0	0.0

a. Draw a position-time graph of the motion of the ball.
b. How far off the ground is the ball at the end of 0.5 s? When would the ball again be this distance from the ground?

9. Use the following position-time graph to find how far the object travels between
a. *t* = 0 s and *t* = 5 s.
b. *t* = 5 s and *t* = 10 s.
c. *t* = 10 s and *t* = 15 s.
d. *t* = 15 s and *t* = 20 s.
e. *t* = 0 s and *t* = 20 s.



10. Use the position-time graph from problem 9 to find the object's velocity between
a. *t* = 0 s and *t* = 5 s.
b. *t* = 5 s and *t* = 10 s.
c. *t* = 10 s and *t* = 15 s.
d. *t* = 15 s and *t* = 20 s.

11. Two cars are headed in the same direction; one travelling 60 km/h is 20 km ahead of the other travelling 80 km/h.
a. Draw a position-time graph showing the motion of the cars.
b. Use your graph to find the time when the faster car overtakes the slower one.

12. Use your graph from Problem 8 to calculate the ball's instantaneous velocity at
a. *t* = 2 s. **b.** *t* = 3 s. **c.** *t* = 4 s.